3. Answer the following questions that relate to the analysis of chemical compounds.

(a) A compound containing the elements C, H, N, and O is analyzed. When a 1.2359 g sample is burned in excess oxygen, 2.241 g of $CO_2(g)$ is formed. The combustion analysis also showed that the sample contained 0.0648 g of H.

(i) Determine the mass, in grams, of C in the 1.2359 g sample of the compound.

(ii) When the compound is analyzed for N content only, the mass percent of N is found to be 28.84 percent. Determine the mass, in grams, of N in the original 1.2359 g sample of the compound.

(iii) Determine the mass, in grams, of O in the original 1.2359 g sample of the compound.

(iv) Determine the empirical formula of the compound.

(b) A different compound, which has the empirical formula CH_2Br, has a vapor density of 6.00 g L^{-1} at 375 K and 0.983 atm. Using these data, determine the following.

(i) The molar mass of the compound

(ii) The molecular formula of the compound

STOP

If you finish before time is called, you may check your work on this part only.
Do not turn to the other part of the test until you are told to do so.

2. Answer the following questions relating to gravimetric analysis.

In the first of two experiments, a student is assigned the task of determining the number of moles of water in one mole of $MgCl_2 \cdot n\,H_2O$. The student collects the data shown in the following table.

Mass of empty container	22.347 g
Initial mass of sample and container	25.825 g
Mass of sample and container after first heating	23.982 g
Mass of sample and container after second heating	23.976 g
Mass of sample and container after third heating	23.977 g

(a) Explain why the student can correctly conclude that the hydrate was heated a sufficient number of times in the experiment.

(b) Use the data above to

(i) calculate the total number of moles of water lost when the sample was heated, and

(ii) determine the formula of the hydrated compound.

(c) A different student heats the hydrate in an uncovered crucible, and some of the solid spatters out of the crucible. This spattering will have what effect on the calculated mass of the water lost by the hydrate? Justify your answer.

In the second experiment, a student is given 2.94 g of a mixture containing anhydrous $MgCl_2$ and KNO_3. To determine the percentage by mass of $MgCl_2$ in the mixture, the student uses excess $AgNO_3(aq)$ to precipitate the chloride ion as $AgCl(s)$.

(d) Starting with the 2.94 g sample of the mixture dissolved in water, briefly describe the steps necessary to quantitatively determine the mass of the AgCl precipitate.

(e) The student determines the mass of the AgCl precipitate to be 5.48 g. On the basis of this information, calculate each of the following.

(i) The number of moles of $MgCl_2$ in the original mixture

(ii) The percent by mass of $MgCl_2$ in the original mixture

3. A 0.150 g sample of solid lead(II) nitrate is added to 125 mL of 0.100 M sodium iodide solution. Assume no change in volume of the solution. The chemical reaction that takes place is represented by the following equation.

$$Pb(NO_3)_2(s) + 2\,NaI(aq) \rightarrow PbI_2(s) + 2\,NaNO_3(aq)$$

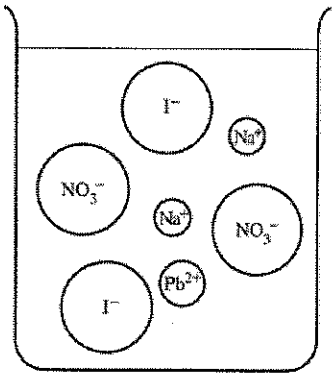
(a) List an appropriate observation that provides evidence of a chemical reaction between the two compounds.

(b) Calculate the number of moles of each reactant.

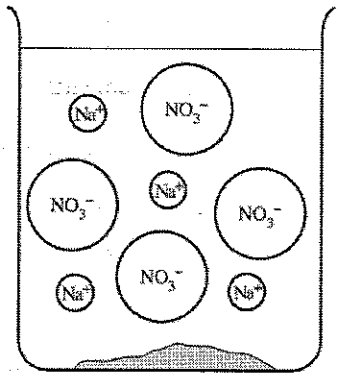
(c) Identify the limiting reactant. Show calculations to support your identification.

(d) Calculate the molar concentration of $NO_3^-(aq)$ in the mixture after the reaction is complete.

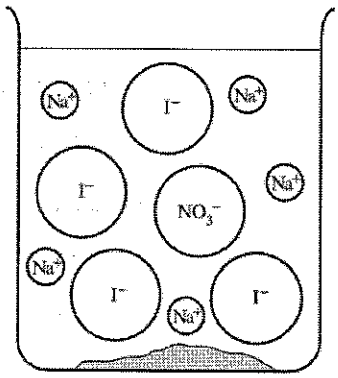
(e) Circle the diagram below that best represents the results after the mixture reacts as completely as possible. Explain the reasoning used in making your choice.



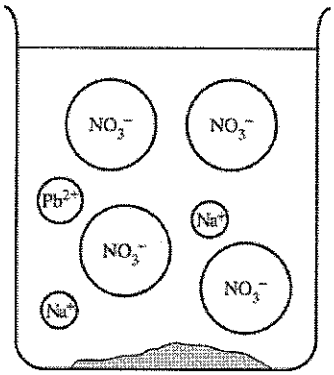
No Precipitate



Solid PbI_2



Solid PbI_2



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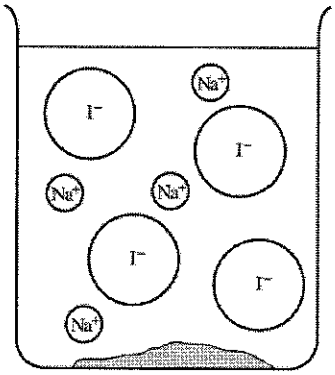

Solid $Pb(NO_3)_2$

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$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

3. The mass of an aqueous solution of H_2O_2 is 6.951 g. The H_2O_2 in the solution decomposes completely according to the reaction represented above. The $O_2(g)$ produced is collected in an inverted graduated tube over water at 23.4°C and has a volume of 182.4 mL when the water levels inside and outside of the tube are the same. The atmospheric pressure in the lab is 762.6 torr, and the equilibrium vapor pressure of water at 23.4°C is 21.6 torr.

(a) Calculate the partial pressure, in torr, of $O_2(g)$ in the gas-collection tube.

(b) Calculate the number of moles of $O_2(g)$ produced in the reaction.

(c) Calculate the mass, in grams, of H_2O_2 that decomposed.

(d) Calculate the percent of H_2O_2, by mass, in the original 6.951 g aqueous sample.

(e) Write the oxidation number of the oxygen atoms in H_2O_2 and the oxidation number of the oxygen atoms in O_2 in the appropriate cells in the table below.

Substance	Oxidation Number of Oxygen Atoms
H_2O_2	
O_2	

(f) Write the balanced oxidation half-reaction for the reaction.

STOP

If you finish before time is called, you may check your work on this part only.
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3. A sample of ore containing the mineral tellurite, TeO_2, was dissolved in acid. The resulting solution was then reacted with a solution of $K_2Cr_2O_7$ to form telluric acid, H_2TeO_4. The unbalanced chemical equation for the reaction is given below.

$$\ldots TeO_2(s) + \ldots Cr_2O_7^{2-}(aq) + \ldots H^+(aq) \rightarrow \ldots H_2TeO_4(aq) + \ldots Cr^{3+}(aq) + \ldots H_2O(l)$$

(a) Identify the molecule or ion that is being oxidized in the reaction.

(b) Give the oxidation number of Cr in the $Cr_2O_7^{2-}(aq)$ ion.

(c) Balance the chemical equation given above by writing the correct lowest whole-number coefficients on the dotted lines.

In the procedure described above, 46.00 mL of 0.03109 *M* $K_2Cr_2O_7$ was added to the ore sample after it was dissolved in acid. When the chemical reaction had progressed as completely as possible, the amount of unreacted (excess) $Cr_2O_7^{2-}(aq)$ was determined by titrating the solution with 0.110 *M* $Fe(NO_3)_2$. The reaction that occurred during the titration is represented by the following balanced equation.

$$6\ Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14\ H^+(aq) \rightarrow 2\ Cr^{3+}(aq) + 6\ Fe^{3+}(aq) + 7\ H_2O(l)$$

A volume of 9.85 mL of 0.110 *M* $Fe(NO_3)_2$ was required to reach the equivalence point.

(d) Calculate the number of moles of excess $Cr_2O_7^{2-}(aq)$ that was titrated.

(e) Calculate the number of moles of $Cr_2O_7^{2-}(aq)$ that reacted with the tellurite.

(f) Calculate the mass, in grams, of tellurite that was in the ore sample.

STOP

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2. A student is assigned the task of determining the mass percent of silver in an alloy of copper and silver by dissolving a sample of the alloy in excess nitric acid and then precipitating the silver as AgCl.

First the student prepares 50. mL of 6 *M* HNO_3.

(a) The student is provided with a stock solution of 16 *M* HNO_3, two 100 mL graduated cylinders that can be read to ±1 mL, a 100 mL beaker that can be read to ±10 mL, safety goggles, rubber gloves, a glass stirring rod, a dropper, and distilled H_2O.

(i) Calculate the volume, in mL, of 16 *M* HNO_3 that the student should use for preparing 50. mL of 6 *M* HNO_3.

(ii) Briefly list the steps of an appropriate and safe procedure for preparing the 50. mL of 6 *M* HNO_3. Only materials selected from those provided to the student (listed above) may be used.

(iii) Explain why it is <u>not</u> necessary to use a volumetric flask (calibrated to 50.00 mL ±0.05 mL) to perform the dilution.

(iv) During the preparation of the solution, the student accidentally spills about 1 mL of 16 *M* HNO_3 on the bench top. The student finds three bottles containing liquids sitting near the spill: a bottle of distilled water, a bottle of 5 percent $NaHCO_3(aq)$, and a bottle of saturated $NaCl(aq)$. Which of the liquids is best to use in cleaning up the spill? Justify your choice.

Then the student pours 25 mL of the 6 *M* HNO_3 into a beaker and adds a 0.6489 g sample of the alloy. After the sample completely reacts with the acid, some saturated $NaCl(aq)$ is added to the beaker, resulting in the formation of an AgCl precipitate. Additional $NaCl(aq)$ is added until no more precipitate is observed to form. The precipitate is filtered, washed, dried, and weighed to constant mass in a filter crucible. The data are shown in the table below.

Mass of sample of copper-silver alloy	0.6489 g
Mass of dry filter crucible	28.7210 g
Mass of filter crucible and precipitate (first weighing)	29.3587 g
Mass of filter crucible and precipitate (second weighing)	29.2599 g
Mass of filter crucible and precipitate (third weighing)	29.2598 g

(b) Calculate the number of moles of AgCl precipitate collected.

(c) Calculate the mass percent of silver in the alloy of copper and silver.